



Radioactivity in the Risø District July-December 2017

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Radioactivity in the Risø District July-December 2017

The cover design features a large rectangular area divided into two main sections. The left section has a background of a grid of squares in shades of light blue and yellow-green. Overlaid on this is a vertical red rectangle containing the text 'DTU Nutech Report' in white. The right section is a solid, bright lime green.

DTU Nutech Report

Jixin Qiao, Kasper G. Andersson and Arne Miller
DTU-Nutech-17(EN)
June 2018

DTU Nutech
Center for Nuclear Technologies



Author: Jixin Qiao, Kasper G. Andersson and Arne Miller
Title: Radioactivity in the Risø District July-December 2017
Center for Nuclear Technologies

DTU-Nutech-17(EN)
June 2018

Abstract (max. 2000 char.): The environmental surveillance of the Risø environment was continued in July-December 2017. The mean concentrations in air were: $0.14 \pm 0.11 \mu\text{Bq m}^{-3}$ of ^{137}Cs , $2.27 \pm 0.72 \text{ mBq m}^{-3}$ of ^7Be and $0.20 \pm 0.14 \text{ mBq m}^{-3}$ of ^{210}Pb (± 1 standard uncertainty). The depositions by precipitation at Risø in the second half of 2016 were: $0.031 \pm 0.005 \text{ Bq m}^{-2}$ of ^{137}Cs , $539 \pm 54 \text{ Bq m}^{-2}$ of ^7Be , $39.0 \pm 4.0 \text{ Bq m}^{-2}$ of ^{210}Pb and $< 1.2 \text{ kBq m}^{-2}$ of ^3H . The average background dose rate (TLD) at Risø (Zone I) was measured as $49 \pm 7 \text{ nSv h}^{-1}$ compared with $53 \pm 4 \text{ nSv h}^{-1}$ (± 1 standard uncertainty) in the four zones around Risø.

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INTRODUCTION

A specific monitoring programme in the vicinity of the nuclear installations at the Risø site is carried out by DTU Nutech on behalf of and as a contractor to Danish Decommissioning (DD). This report presents the analytical results of the monitoring and sampling carried out in the period July-December 2017. The materials and methods used in connection with the monitoring programme are described in pages 23-24.

Table 1. Radionuclides in ground level air collected at Risø (cf. Figs. 1, 1.1 and 1.2), July-December 2017 (Unit: $\mu\text{Bq m}^{-3}$)

Date	^7Be	^{137}Cs	^{210}Pb
04-Jul-17 – 10-Jul-17	3293(10%)	0.058(15%)	141(10%)
10-Jul-17 – 17-Jul-17	3021(10%)	0.043(15%)	134(10%)
17-Jul-17 – 23-Jul-17	3142(10%)	0.093(12%)	247(10%)
23-Jul-17 – 31-Jul-17	2789(10%)	0.081(12%)	194(10%)
31-Jul-17 – 07-Aug-17	2277(10%)	0.042(16%)	130(10%)
07-Aug-17 – 14-Aug-17	3193(10%)	0.059(14%)	164(10%)
14-Aug-17 – 21-Aug-17	3088(10%)	0.053(14%)	191(10%)
21-Aug-17 – 28-Aug-17	2288(10%)	0.081(12%)	183(10%)
28-Aug-17 – 04-Sep-17	2344(10%)	0.081(12%)	178(10%)
04-Sep-17 – 11-Sep-17	1481(10%)	0.053(12%)	165(10%)
11-Sep-17 – 18-Sep-17	1253(10%)	0.077(11%)	122(10%)
18-Sep-17 – 26-Sep-17	2204(10%)	0.484(10%)	552(10%)
26-Sep-17 – 03-Oct-17	3283(10%)	0.508(10%)	645(10%)
03-Oct-17 – 10-Oct-17	1482(10%)	0.078(14%)	91(10%)
10-Oct-17 – 17-Oct-17	2808(10%)	0.101(11%)	459(10%)
17-Oct-17 – 23-Oct-17	2372(10%)	0.154(12%)	302(10%)
23-Oct-17 – 30-Oct-17	1470(10%)	0.166(11%)	85(10%)
30-Oct-17 – 06-Nov-17	3271(10%)	0.132(11%)	131(10%)
06-Nov-17 – 13-Nov-17	1702(10%)	0.186(10%)	130(10%)
13-Nov-17 – 20-Nov-17	1483(10%)	0.159(11%)	62(10%)
20-Nov-17 – 27-Nov-17	2369(10%)	0.211(12%)	235(10%)
27-Nov-17 – 04-Dec-17	979(10%)	0.196(11%)	102(10%)
04-Dec-17 – 11-Dec-17	1797(10%)	0.097(11%)	71(10%)
11-Dec-17 – 18-Dec-17	1792(10%)	0.255(12%)	205(10%)
18-Dec-17 – 27-Dec-17	1510(10%)	0.156(12%)	104(10%)
27-Dec-17 – 03-Jan-18	2233(10%)	0.142(13%)	117(10%)
Mean	2266	0.144	198
SD	723	0.118	144

*Figures in brackets are relative standard uncertainties

Table 2.1. Radionuclides in precipitation in the 10 m² rain collector at Risø (cf. Fig. 8.1), July - December 2017. (Unit: Bq m⁻³)

Month	⁷ Be	¹³⁷ Cs	²¹⁰ Pb
July	2176(10%)*	0.066(28%)	85(10%)
August	2276(10%)	0.124(15%)	117(10%)
September	1042(10%)	0.067(14%)	80(10%)
October	1513(10%)	0.106(13%)	149(10%)
November	1554(10%)	0.061(23%)	70(10%)
December	1923(10%)	0.035(42%)	85(10%)

*Figures in brackets are relative standard uncertainties

Table 2.2. Radionuclides in precipitation in the 10 m² rain collector at Risø (cf. Fig. 8.1), July - December 2017. (Unit: Bq m⁻²)

Month	Precipitation (m)	⁷ Be	¹³⁷ Cs	²¹⁰ Pb
July	0.070(10%)*	152.5(14%)	0.0046(30%)	6.0(14%)
August	0.046(10%)	105.4(14%)	0.0057(18%)	5.4(14%)
September	0.123(10%)	128.5(14%)	0.0082(18%)	9.8(14%)
October	0.073(10%)	111.3(14%)	0.0078(16%)	11.0(14%)
November	0.050(10%)	77.1(14%)	0.0030(25%)	3.5(14%)
December	0.039(10%)	75.7(14%)	0.0014(43%)	3.3(14%)
Sum	0.401(5%)	539.2(10%)	0.0307(15%)	39.0(10%)

*Figures in brackets are relative standard uncertainties

Table 2.3. Tritium in precipitation collected at Risø (cf. Figs. 1, 2.3.1 and 2.3.2). July - December 2017. (Unit: kBq m⁻³)

Month	10 m ² rain collector*
July	< 1.7
August	< 1.7
September	1.7(34%) ^a
October	8.0(12%) ^b
November	< 1.7
December	< 1.7
Double determinations*.	

^a Figures in brackets are relative standard uncertainties

^b Although the value is slightly higher here, it is still low and in line with variation we have previously seen (cf. Fig. 2.3.2).

Table 2.4. Tritium in precipitation collected at Risø (cf. Fig. 1). July - December 2017. (Unit: kBq m⁻²)

Month	Precipitation (m)	10 m ² rain collector
July	0.070(10%) ^a	< 0.120
August	0.046(10%)	< 0.079
September	0.123(10%)	0.209(35%)
October	0.073(10%)	0.584(19%)
November	0.050(10%)	< 0.085
December	0.039(10%)	< 0.067
Sum	0.401(5%)	<1.144

^a Figures in brackets are relative standard uncertainties

Table 3.1. Radionuclides in sediment samples collected at Bolund in Roskilde Fjord.(cf. Fig. 3.1) July - December 2017. (Unit: Bq kg⁻¹ dry)

Date	¹³⁷ Cs	K*
18 July	1.5(14%) ^a	13.4(10%)
*Unit: g kg ⁻¹ dry		

^a Figures in brackets are relative standard uncertainties

Table 4.1. Radionuclides in seawater collected in Roskilde Fjord (cf. Fig. 4.1) July - December 2017. (Unit: Bq m⁻³)

Date	¹³⁷ Cs
1 July	8.7(12%)

Table 4.2. Tritium in seawater collected in Roskilde Fjord (Risø pier) (cf. Fig. 4.2) July - December 2017^a.*

Month	kBq m ⁻³
September	<1.7
December	<1.7
* Double determinations	

^a Figures in brackets are relative standard uncertainties

Table 5.1. Radionuclides in grass (* snow) collected at Risø near the Waste Treatment Station, location I P3, Fig. 1, July - December 2017. (**Measured on bulked ash samples)

Week no. or month	Date	K (g kg ⁻¹ fresh)	¹³⁷ Cs (Bq kg ⁻¹ fresh)	¹³⁷ Cs (Bq m ⁻²)
27	4 July	4.5(10%) ^a	<0.4	
29	17 July	4.8(10%)	<0.4	
31	31 July	5.2(10%)	<0.6	
33	12 August	5.4(10%)	<0.3	
35	28 August	4.7(10%)	<0.4	
37	11 September	5.7(10%)	<0.4	
39	26 September	5.7(10%)	<0.6	
41	10 October	4.2(10%)	<0.3	
43	23 October	3.2(10%)	<0.3	
45	6 November	3.7(10%)	<0.3	
47	20 November	3.6(10%)	<0.3	
49	4 December	3.1(10%)	<0.2	
51	18 December	2.8(10%)	<0.2	
**July		5.3(10%)	0.065(35%)	0.017(24%)
**August		5.9(10%)	0.027(22%)	0.022(26%)
**September		6.2(10%)	0.050(22%)	0.010(28%)
**October		4.0(10%)	0.102(18%)	0.037(31%)
**November		4.1(10%)	0.052(44%)	0.029(27%)
**December		2.5(10%)	0.171(12%)	0.108(20%)

^a Figures in brackets are relative standard uncertainties

Table 5.2. Radionuclides in Fucus vesiculosus collected at Bolund in Roskilde Fjord. July - December 2017. (Unit: Bq kg⁻¹ dry)

Date	¹³⁷ Cs	K*	% dry matter
18 July	2.2(12%) ^a	29(10%)	21(10%)
*Unit: g kg ⁻¹ dry			

^a Figures in brackets are relative standard uncertainties

Table 7.1. Waste water collected at Risø (cf. Fig. 1), July - December 2017.

Week number	Total beta (eqv. mg KCl l ⁻¹)	¹³⁷ Cs (Bq m ⁻³)	¹³¹ I (Bq m ⁻³)	²²⁶ Ra (Bq m ⁻³)
27	86(10%)	<132	<134	<311
28	105(13%)	<125	<131	<307
29	114(10%)	<141	<142	<315
30	39(11%)	<121	<120	<255
31	89(11%)	<134	<152	<286
32	87(11%)	<129	<131	<272
33	62(10%)	<116	<125	<253
34	75(10%)	<116	<119	<249
35	80(10%)	<136	<144	<291
36	89(13%)	<110	<116	<249
37	62(10%)	<146	<143	<310
38	41(11%)	<138	<146	<321
39	68(10%)	<122	<154	<265
40	70(10%)	<118	<124	<263
41	43(12%)	<132	<135	<266
42	67(11%)	<63	<65	<136
43	72(13%)	<119	<126	<249
44	56(11%)	<127	<128	<266
45	64(12%)	<116	<127	<256
46	87(12%)	<119	<126	<272
47	83(10%)	<122	<121	<249
48	64(11%)	<125	<129	<257
49	50(10%)	<124	<128	<271
50	33(10%)	<139	<140	<285
51	94(11%)	<120	<128	<269
52	85(11%)	<68	<92	<148
Mean	72.0	<121	<128	<264
SD	20.4			

^a Figures in brackets are relative standard uncertainties

Table 8.1. Background dose rates around the border of Risø (cf. Fig. 8.1) measured with thermoluminescence dosimeters (TLD) in the period May 2017– October 2017. (Results are normalized to nSv h^{-1})

Location	nSv h^{-1} ^a
1	36(10%) ^a
2	49(10%)
3	49(10%)
4	52(10%)
5	52(10%)
6	55(10%)
Mean	49(5%)

^a Figures in brackets are relative standard uncertainties

Table 8.2. Background dose rates around Risø (cf. Fig. 8.2 and Fig. 1) measured with thermoluminescence dosimeters (TLD) in the period May 2017– October 2017. (Results are normalized to nSv h^{-1})

Risø zone	Location	nSv h^{-1} ^a
I	1	48(10%) ^a
I	2	46(10%)
I	3	71(10%)
I	4	49(10%)
I	5	54(10%)
Mean		54(5%)
II	P1	48(10%)
II	P2	56(10%)
II	P3	43(10%)
II	P4	40(10%)
Mean		47(10%)
III	P1	65(10%)
III	P2	50(10%)
III	P3	54(10%)
Mean		56(6%)
IV	P1	41(10%)
IV	P2	46(10%)
IV	P3	54(10%)
IV	P4	44(10%)
IV	P5	52(10%)
IV	P6	50(10%)
IV	P7	66(10%)
Mean		50(4%)
V	P1	67(10%)
V	P2	53(10%)
V	P3	66(10%)
V	P4	48(10%)
V	P5	52(10%)
V	P6	- ^b
V	P7	50(10%)
V	P8	66(10%)
V	P9	50(10%)
V	P10	59(10%)
Mean		57(4%)

^a Figures in brackets are relative standard uncertainties

^b This denotes that the TLD dosimeter has been lost during the exposure period

Table 8.3. Terrestrial dose rates at the Risø zones (cf. Fig. 8.2 and Fig. 1) July – December 2017. Measured with a NaI(Tl) detector. (Unit: nSv h⁻¹)

Risø zone	Location	October
I	P1	44(10%) ^a
I	P2	53(10%)
I	P3	322(10%)
I	P4	44(10%)
I	P5	56(10%)
Mean		104(5%)
II	P1	43(10%)
II	P2	47(10%)
II	P3	41(10%)
II	P4	38(10%)
Mean		42(5%)
III	P1	48(10%)
III	P2	46(10%)
III	P3	40(10%)
Mean		45(6%)
IV	P1	36(10%)
IV	P2	48(10%)
IV	P3	45(10%)
IV	P4	43(10%)
IV	P5	41(10%)
IV	P6	43(10%)
IV	P7	48(10%)
Mean		43(4%)
V	P1	53(10%)
V	P2	55(10%)
V	P3	51(10%)
V	P4	45(10%)
V	P5	43(10%)
V	P6	45(10%)
V	P7	47(10%)
V	P7a	39(10%)
V	P8	44(10%)
V	P9	52(10%)
V	P10	38(10%)
Mean		51(4%)

^a Figures in brackets are relative standard uncertainties

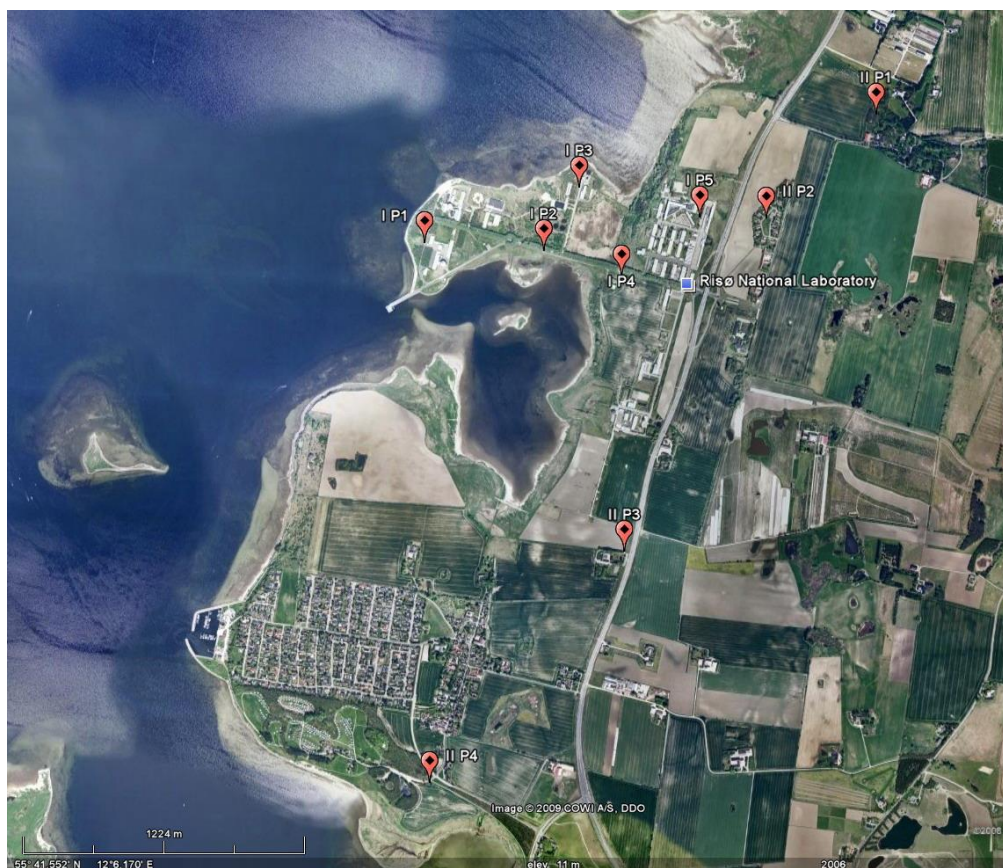


Fig. 1. Locations for measurements of gamma-background radiation Zone I and II (cf. Tables 8.2 and 8.3)

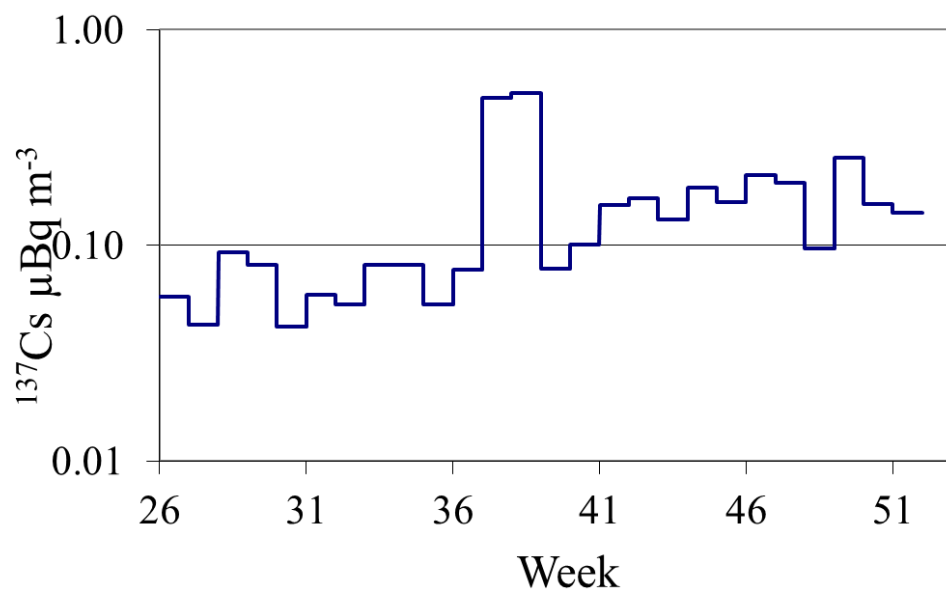


Fig. 1.1. Caesium-137 in ground level air collected at Risø in July-December 2017. (Unit: $\mu\text{Bq m}^{-3}$)

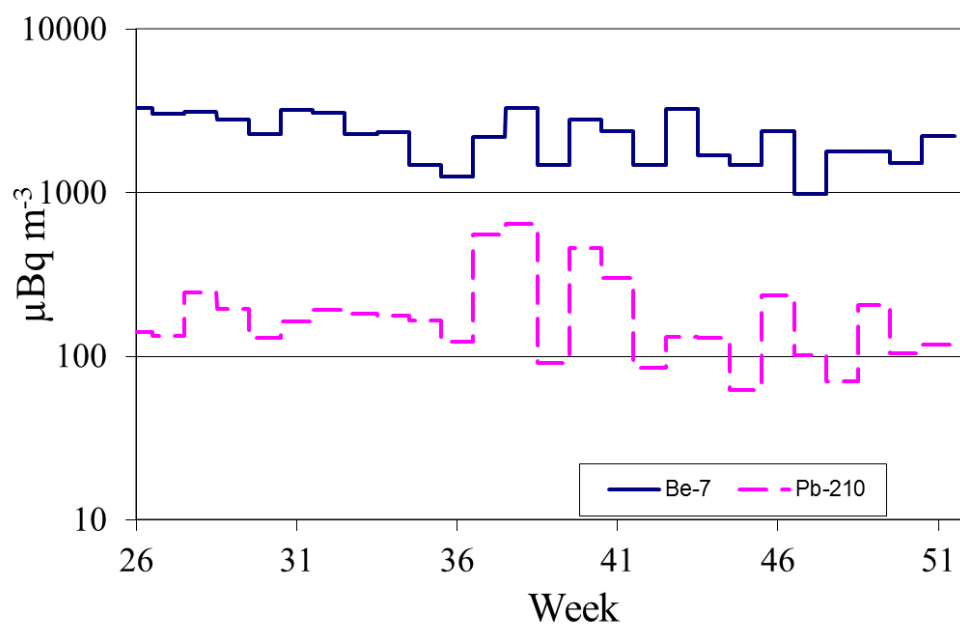


Fig. 1.2. Beryllium-7 and Lead-210 in ground level air collected at Risø in July-December 2017. (Unit: $\mu\text{Bq m}^{-3}$)

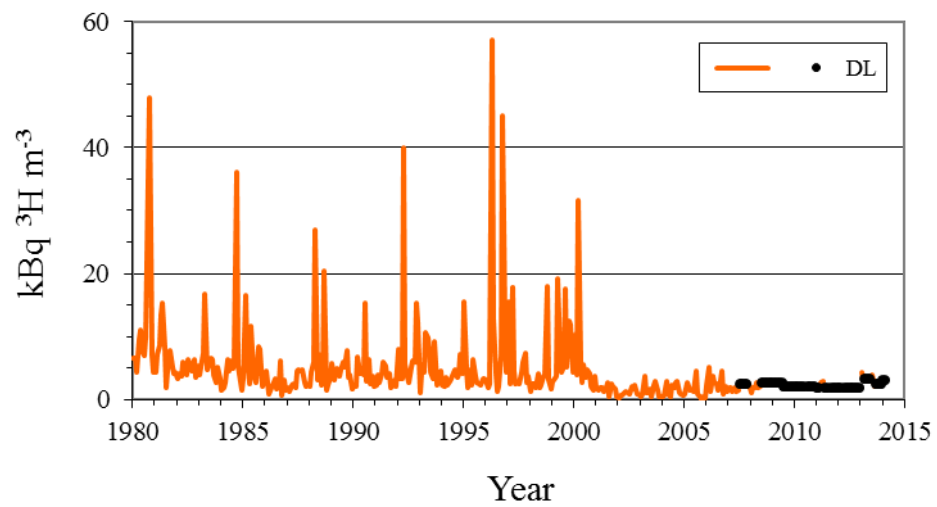


Fig. 2.3.1. Tritium in precipitation collected at Risø (1 m² rain collector) 1980 - 2013. (Unit: kBq m⁻³; DL = detection limit . This rain collector was taken out of operation in 2013.

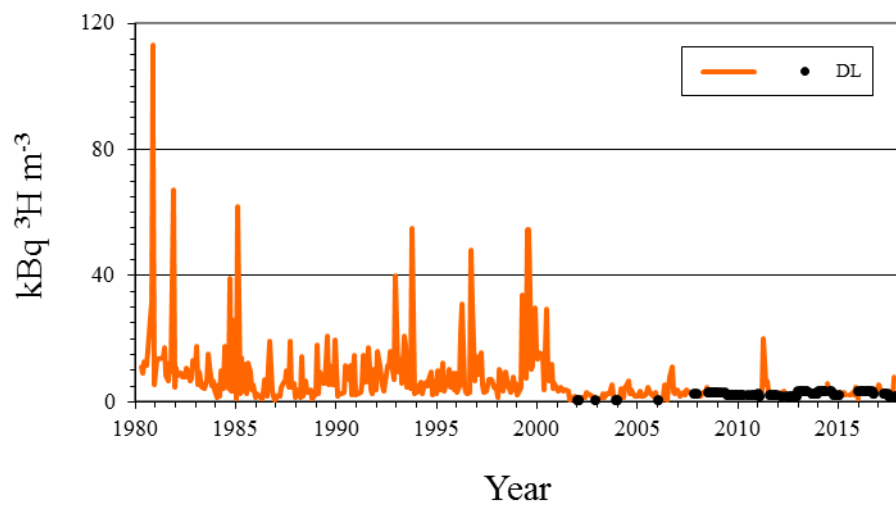


Fig. 2.3.2. Tritium in precipitation collected at Risø (10 m² rain collector) 1980 - 2017. (Unit: kBq m⁻³; DL = detection limit)

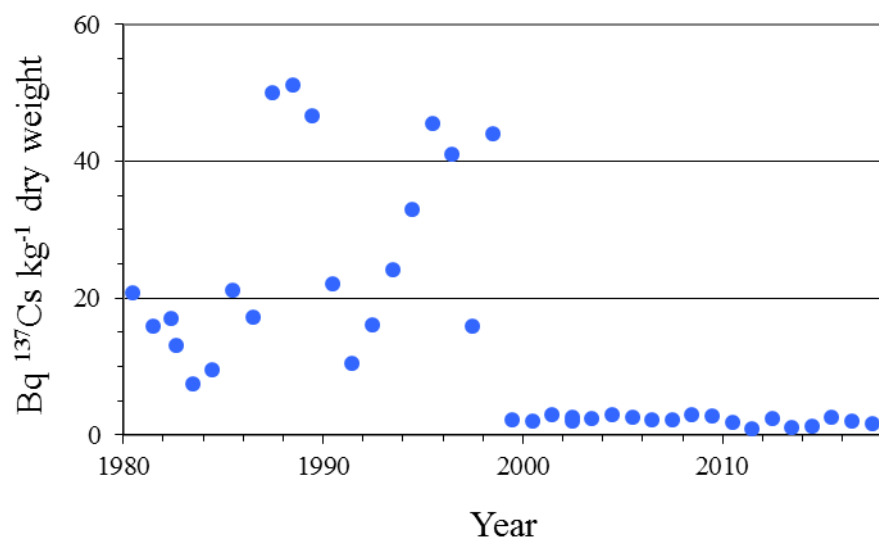


Fig. 3.1. Caesium-137 in sediment samples collected at Bolund in Roskilde Fjord. 1980 – 2017. (Unit: Bq kg^{-1} dry matter)

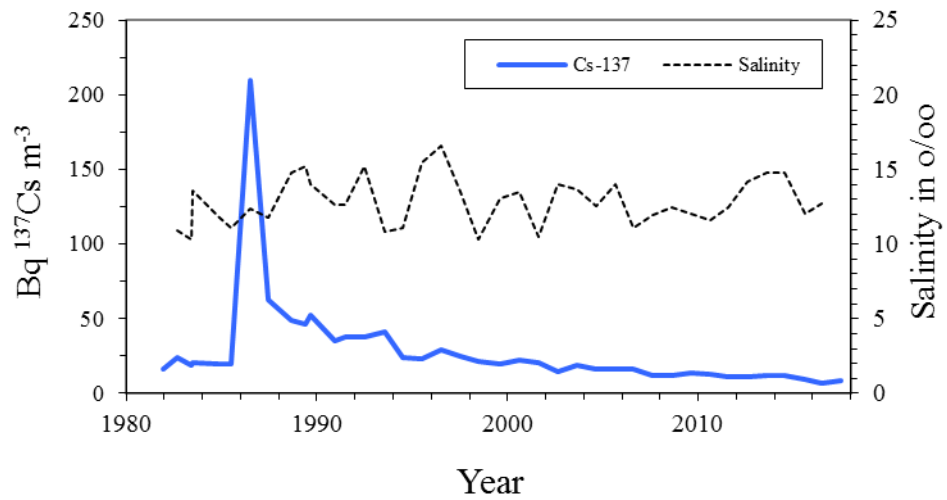


Fig. 4.1. Caesium-137 in seawater collected in Roskilde Fjord 1980 - 2017.
(Unit: $Bq\ m^{-3}$)

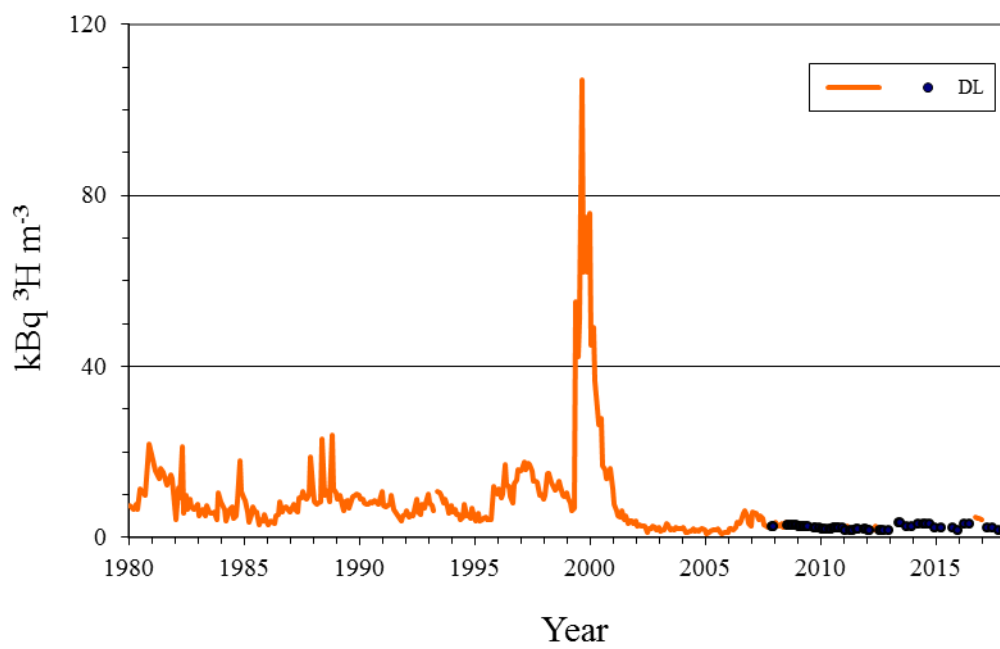
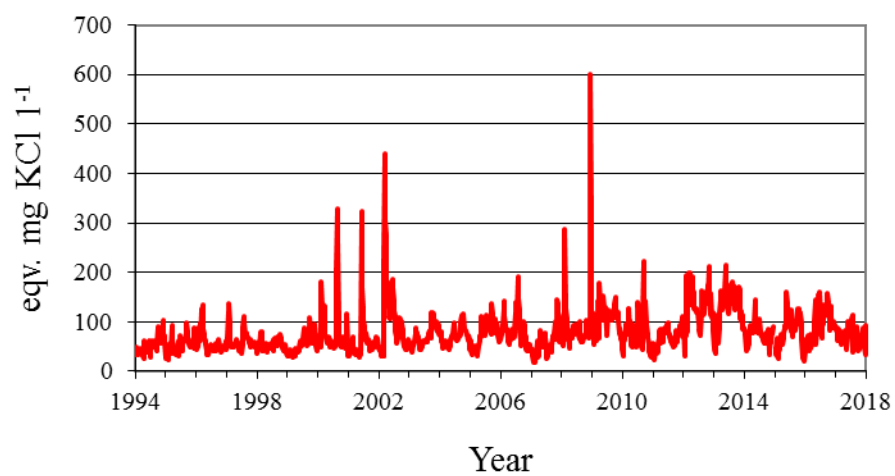


Fig. 4.2. Tritium in seawater collected in Roskilde Fjord 1980 - 2017.
(Unit: $kBq\ m^{-3}$; DL = detection limit)



*Fig. 7.1. Total-beta radioactivity in waste water collected at Risø 1994 - 2017.
(Unit: eqv. mg KCl l⁻¹)*

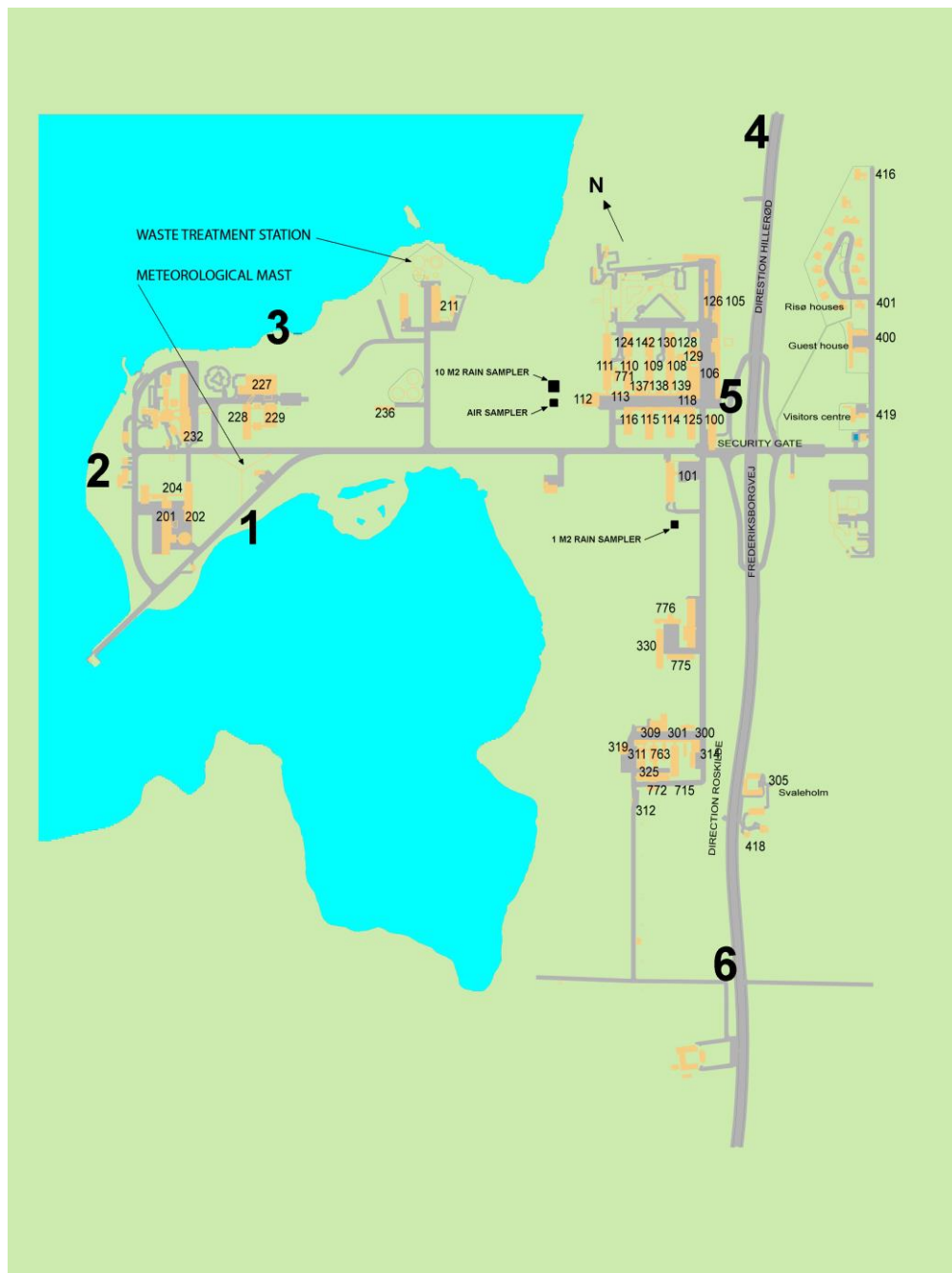


Fig. 8.1. Locations (1-6) for TLD measurements around the border of Risø (cf. Table 8.1).

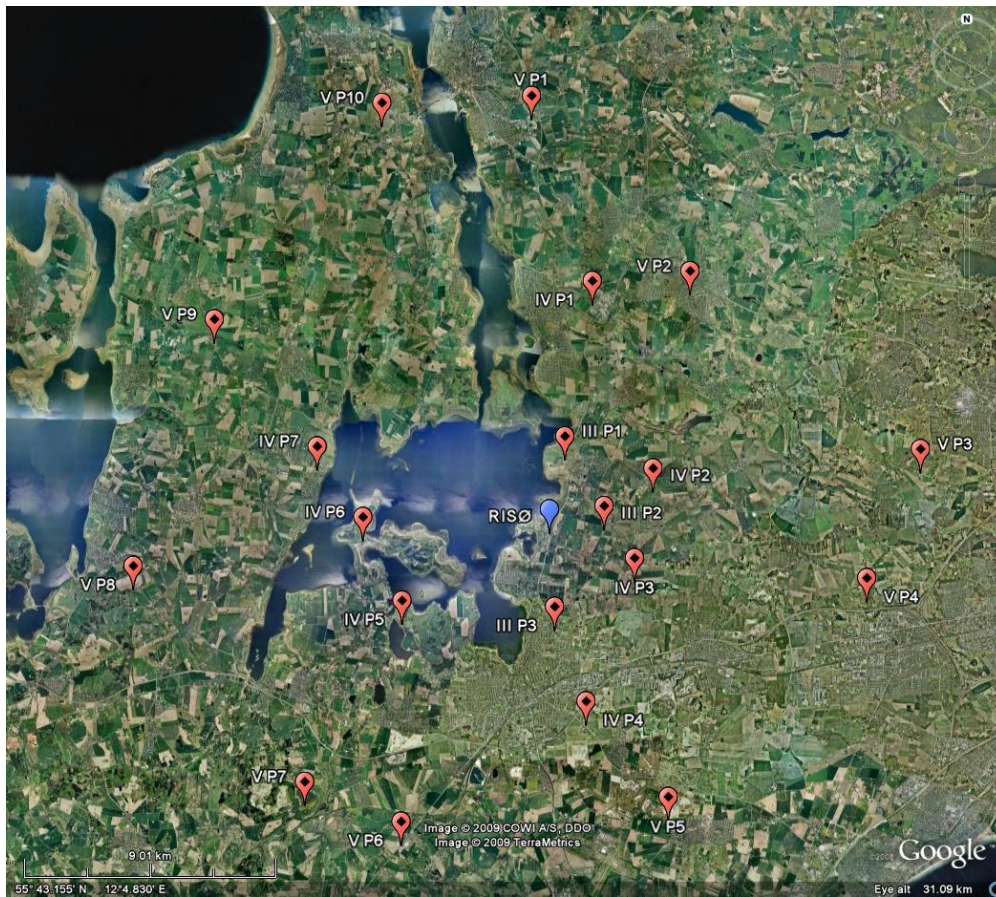


Fig. 8.2. Locations for measurements of background radiation around Risø in Zones III, IV and V.

MATERIALS AND METHODS

External gamma dose rate monitoring

Monitoring of external gamma dose rate is carried out with the following devices

- Thermoluminescence dosimeters TLD: LiF, measurement frequency annually from May to April. TLD equipment manufacturer: ALNOR/RADOS
- NaI detector: 3x3 inch, SAM 935 Surveillance and Measurement System, Berkeley Nucleonics Cooperation, USA, visual read-out

Calibration of TLD is carried out by irradiation of dosimeters at a calibration irradiator. Traceability of delivered doses is ensured through calibration of the dose rate of the calibration irradiator by the National Institute of Radiation Protection (NIS). Calibration has been verified by measurement with ionisation chamber from NPL, UK. The NaI detector is calibrated periodically vs. a Reuter Stokes high-pressure ionisation chamber.

Air sampler

The sampler at Risø is manufactured by DTU. Air is drawn through a polypropylene filter at a rate of about 2000 m³/h. The filter is normally changed weekly. The flow rate is monitored by a gas meter connected to a shunt. The gas meter reading is compared to that of a reference gas meter intermittently.

DTU analyse the filters by gamma spectrometry shortly after filter change to check for the presence of short-lived man-made radionuclides. The air filters are subsequently stored for a minimum of one week to allow for decay of short-lived naturally occurring radionuclides before repeated gamma analysis. Filters are analysed for ¹³⁷Cs, ⁷Be and ²¹⁰Pb and other gamma emitters.

Deposition collector

The Risø site operates a large rain collector of 10 m². The collector is heated and water is passed through an ion exchange column to a large tank. The 10 m² collector provides monthly samples of rain water analysed for tritium and ion exchange resin which is analysed by gamma spectrometry for ⁷Be, ¹³⁷Cs and ²¹⁰Pb and other gamma emitters.

Water and sediment

A waste water sample from the Waste Treatment Station is collected weekly and analysed for total beta radioactivity and the radionuclides ¹³¹I, ¹³⁷Cs and ²²⁶Ra. Water samples from Roskilde Fjord are collected each quarter and analysed for tritium, annually for ¹³⁷Cs. A sediment sample is collected annually from Roskilde Fjord and analysed for ¹³⁷Cs.

Terrestrial and aquatic biota and flora

Grass samples are collected weekly at the Risø site and analysed by gamma spectrometry. Samples are bulked to monthly samples which are analysed for ¹³⁷Cs.

Seaweed samples are collected annually from Roskilde Fjord at Risø and analysed for ¹³⁷Cs.

Sample reception and preparation

Sample identification numbers are entered in log books. Sample preparation methods include drying, freeze drying, ashing, sorting and sieving. Selected samples are archived.

Sample measurements

Radioactivity in samples is measured by total beta counting and gamma spectrometry.

Measurement devices

- Ge detectors for gamma spectrometry. Calibration of detectors is based on mixed-nuclide standards used occasionally. Monthly checks are made of detector efficiency and energy resolution. Background measurements of gamma systems are made a few times per year.
- Low-level Geiger-Müller counters for total beta counting, manufactured by DTU. Calibration based on standards of KCl. Counting efficiency and background are checked monthly.
- Liquid scintillation spectrometer for analysis of tritium in water. Samples are analysed with a calibration standard.

Analytical results, data handling and reporting tools

Analytical results are printed on paper, recorded in log books and stored in a data base on intranet. Results below detection limits recorded as such. Spreadsheets are used for calculating results from raw data.

Quality assurance, laboratory accreditation and intercomparison exercises

Analytical results are checked by experienced staff and discussed with senior scientists if questions arise.

DTU is accredited to testing for radioactivity by DANAK according to the international standard ISO 17025. The accreditation covers testing for certain non-gamma emitting radionuclides but not for radionuclides occurring in the environment and food in general.

DTU participate regularly in international intercomparisons on laboratory analyses of radionuclides.

CONCLUSIONS

This report shows the results of the environmental surveillance monitoring programme carried out at and around the Risø site in July-December 2017. The mean concentrations in air were: $0.14 \pm 0.11 \text{ } \mu\text{Bq m}^{-3}$ of ^{137}Cs , $2.27 \pm 0.72 \text{ mBq m}^{-3}$ of ^7Be and $0.20 \pm 0.14 \text{ mBq m}^{-3}$ of ^{210}Pb (± 1 standard uncertainty). The depositions by precipitation at Risø in the second half of 2016 were: $0.031 \pm 0.005 \text{ Bq m}^{-2}$ of ^{137}Cs , $539 \pm 54 \text{ Bq m}^{-2}$ of ^7Be , $39.0 \pm 4.0 \text{ Bq m}^{-2}$ of ^{210}Pb and $< 1.2 \text{ kBq m}^{-2}$ of ^3H . The average background dose rate (TLD) at Risø (Zone I) was measured as $49 \pm 7 \text{ nSv h}^{-1}$ compared with $53 \pm 4 \text{ nSv h}^{-1}$ (± 1 standard uncertainty) in the four zones around Risø. None of the recorded levels of radioactivity and radiation have given rise to concern.

Center for Nuclear Technologies is Denmark's national competency center for nuclear technology. With roots in research in the peaceful use of nuclear power, DTU Nutech works with the applications of ionizing radiation and radioactive substances for the benefit of society.

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